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ORIGINAL ARTICLE

A study on the optimization of thickness of rails and stiles of panel door shutters

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Abstract There is a need for optimizing the utilization of timber used in rails and stiles of panel door shutters to achieve economy in panel door manufacturing. A study was carried out to optimize the timber used in the manufacture of panel door shutters without affecting the performance of the door shutter. Keeping aesthetics in view the study was limited to reducing only the thickness of rails and stiles to 25 and 30 mm whereas the specified thickness is 35 mm. Panel door shutters of thickness 25, 30 and 35 mm, and of size 2005 mm (H) × 700, 900 and 1100 mm (W) were made and tested for their performance as per Indian Standard specification on timber panelled and glazed shutters (IS: 1003 (Part 1), 2003). The results revealed that the doors made of 30 mm thick rails and stiles, are comparable with doors made out of 35 mm thick rails and stiles for all widths. Hence, 30 mm thickness can be recommended for panel door manufacturing, which will save about 15% consumption of wood, thereby saving the natural resources.

Keywords Panel door shutters · Economy in utilization · Natural resources · Performance

Introduction

Door is an important component of any building because of its function, size and location, and also forms the visual focal point. The most commonly used doors are flush door, panel door and high density fibreboard molded skin door in housing applications. Among these door types, panel door continues to be the most popular design till today and the reason for this popularity is mainly due to the fact this offers maximum flexibility. In panel door shutters, rails and stiles are the structural parts, constructed in the form of frame work, and the panels are mainly the infilling and hardly contribute to the strength and are free from warp and bow. The frame work consists of vertical stiles, top rail, intermediate rail and bottom rail as shown in Fig. 1. The panel insert as per Indian Standards can be plywood, blockboard, particle board, hard board and asbestos cement boards. The user has to decide which particular type of panel insert meets their requirement. The thickness of these panel inserts ranges from 12 mm and above for blockboard and 9–12 mm for other panels, depending on the type of material used. Solid wood, wood-based or other lignocellulosic panel materials could be infill material. In residential buildings, houses and apartments, panel doors are the most favoured ones, mainly because of aesthetics, durability and cost factors.

With the introduction of new composites and plantation timber there is a need of updating the specification and optimizing the dimensions of rails and stiles of panel door shutters which will be useful for door manufacturers, designers, engineers and architects to optimize the usage of materials without compromising the performance of door shutters and thereby saving the natural resources. Any amount of wood conservation is highly desirable in the present context of wood raw material shortage.

The thickness of the panel inserts can be reduced without affecting the performance of the door (Guruva Reddy and Jagadeesh 1982). With the introduction of new generation of panel products and composites, whose properties are much different from the conventional species used in panel doors, there is a scope in updating the panel

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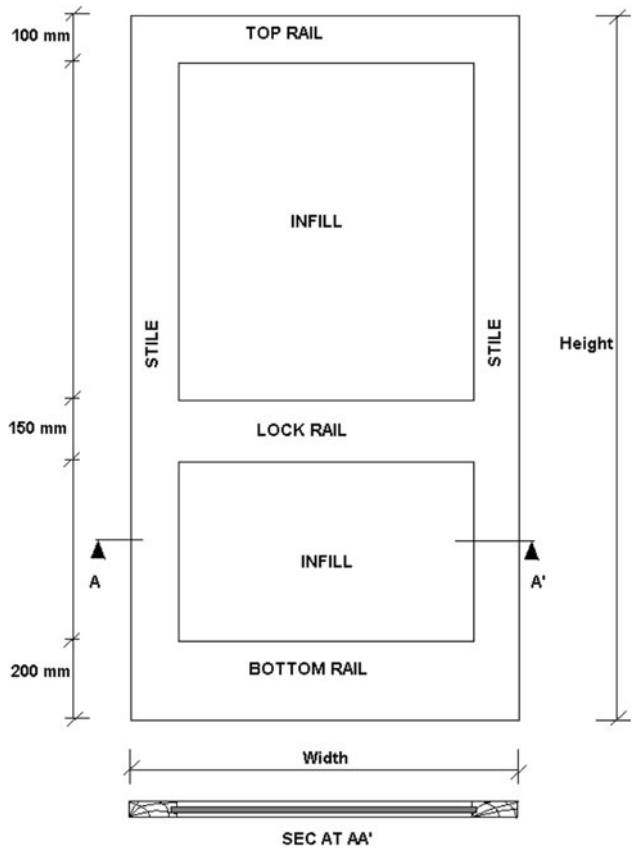

Fig. 1 Construction details of panel door shutter

door specification (IS:1003, 2003), which includes the species of timber, construction and workmanship, dimensions of components and their tolerances and tests.

It is found that on applying principles of glue-lam technique, it is possible to obtain high grade rails and stiles from plantation species like silver oak and poplar. By combining laminated wood stile and rail with panel materials, it is possible to fabricate good quality panel doors and flush door shutters (Jagadeesh et al. 1998).

This study was taken up to reduce the consumption of wood and to achieve the economy in utilization of timber through optimization of thickness of rails and stiles in the manufacture of panel door shutters. The objectives of this study are to process panel door shutters of thickness 25, 30 and 35 mm (for rails and stiles) and of size 2005 mm (H) and 700, 900, and 1100 mm (W) from species of silver oak, and test their performance as per Indian Standard specification on timber panelled and glazed Shutters (IS:1003 (Part 1), 2003).

Materials and methods

Major components of the panel door shutters are rails, stiles and panel inserts. Keeping aesthetics in view the study was limited to reduce only the thickness of rails and stiles to 25 and 30 mm, where as the specified thickness is 35 mm. The species selected for this study is silver oak, which is one of the recommended species as per Indian Standard specification on classification of Indian timbers for door and window shutters and frames. (IS:12896, 1990). Silver oak logs were processed for the required dimensions and seasoned. Plywood and particle boards of 12 mm thickness were used as panel inserts. Panel door shutters were prepared as per Indian Standard specification on timber panelled and glazed shutters (IS:1003 (Part 1), 2003) for the dimensions as shown in Table 1.

Table 1 Panel door shutters of different dimensions

Type	Height (mm)	Width (mm)	Thickness (mm)
A1	2005	700	25
B1	2005	700	30
C1	2005	700	35
A2	2005	900	25
B2	2005	900	30
C2	2005	900	35
B3	2005	1100	30
C3	2005	1100	35

The moisture content of rails and stiles was found to be in the range of 10–12%. Mortise and tenon joints were used for fabricating the door shutters. Panels were inserted by making groove without beading. Polyvinyl acetate resin was used for gluing the joints. Two samples in each type of door shutters, as mentioned above in Table 1, were fabricated as per Indian Standard specification on timber panelled and glazed shutters (IS:1003 (Part 1), 2003) and tested as per Door shutters-methods of tests (IS:4020, 1998) for their performance.

Results and discussion

The results of the performance testing of door shutters, made with 25, 30 and 35 mm thick rails and stiles, are given in Tables 2, 3 and 4, respectively. The comparison of Edge loading and buckling resistance tests is shown in Figs. 2 and 3, respectively. From the results, it is observed that the door shutters made with 30 and 35 mm thick rails and stiles, are comparable and Door shutters made with 25 mm thick rails and stiles are not suitable for door widths above 900 mm, where as Door shutters made with 30 mm thick rails and stiles are suitable for widths up to 1100 mm.

From the results it is also observed that the deflection in flexure, buckling and edge loading tests for all the door

Table 2 Results of 25 mm thick panel door shutters

S. No	Tests	Minimum value for conformity as per IS1003: part 1 : 2003	Results	
			A1	A2
1	Dimensions (mm)			
	Length	Length ± 5 mm	2009	2009
	Width	Width ± 5 mm	707.5	906
	Thickness	Thickness ± 1 mm	25.54	25.63
2	Squareness (mm) Deviation per 500 mm length	Squareness not more than 0.5 mm per 500 mm length	0.8	1.92
3	General flatness (mm)			
	Twisting	Twist, cupping and warping not greater than 6 mm	0.54	0.575
	Cupping		0.75	0.7
	Warping		0.6	0.75
4	Local planeness (mm)	Depth of deviation not greater than 0.5 mm	0	0
5	Flexure (mm)			
	15 min after loading 50 kg	Deflection at maximum load not greater than 1/30 of length and 1/15 of	At 30 kg load, door rests on the frame[a]	At 20 kg load, door rests on the frame[a]
	3 min after load removal	width, whichever is less. Residual deflection not greater than 1/10 of max deflection		
6	Impact indentation	No cracking, tearing or delamination.	No crack or deformation	No crack or deformation
		Depth of indentation not greater than 0.2 mm	Max. Indentation = 0.1 mm	Max. Indentation = 0.2 mm
7	Edge loading test (deflection in mm) Initial reading	Deflection at max. Load not greater than 5 mm. Residual deflection after removal of load not greater than 0.5 mm	10.8	12.8
	After 15 min of 100 kg loading	Not more than 2 mm during loading	4.9	5.4
	3 min after load removal	No residual buckling after load removal	No residual buckling	No residual buckling
8	Shock resistance			
	Soft and light body impact	No visible damage	No visible damage or delamination	No visible damage or delamination
	Soft and Heavy body impact	No visible damage	No visible damage or delamination	No visible damage or delamination
9	Buckling resistance test (deflection in mm)	No deterioration	No deterioration	No deterioration
	After 5 min of 40 kg loading	Initial deflection not more than 50 mm.	146	187.8
	15 min after load removal	Residual deformation after 15 min of load removal not greater than 5 mm	21.7	32.0
10	Slamming test	No visible damage after 50 drops.	No visible damage	No visible damage
11	Misuse	No permanent deformation of the fixing or any other part of the doorstep in hindering it's normal working after the test.	No permanent deformation	No permanent deformation

[a] Maximum deflection limit of door testing equipment for Flexure test: 120 mm

shutters, including 35 mm thick door shutters, exceeds the maximum permissible deflection as prescribed in Indian Standard specification on timber panelled and glazed shutters (IS:1003 (Part 1), 2003), which is mainly because of the fact that the construction of panel door shutter is not same as flush door shutters (prescribed values for panel

Table 3 Results of 30 mm thick panel door shutters

S. No	Tests	Minimum value for conformity	B1	B2	B3
1	Dimensions (mm)				
	Length	Length ± 5 mm	2002.5	2000	2001.5
	Width	Width ± 5 mm	69.75	900	1097.5
	Thickness	Thickness ± 1 mm	213.1	30.1	30.4
2	Squareness (mm) deviation per 500 mm length	Squareness not more than 0.5 mm per 500 mm length	0.625	2.7	1.06
3	General flatness (mm)				
	Twisting	Twist, cupping and Warping not greater than 6 mm	0.82	0.4	0.075
	Cupping		0.67	0.98	0.1
	Warping		0.5	1.42	0.3
4	Local planeness (mm)	Depth of deviation not greater than 0.5 mm	0	0	0
5	Flexure, mm 15 min after loading 50 kg 3 min after load removal	Deflection at maximum load not greater than 1/30 of length and 1/15 of width, whichever is less. Residual deflection not greater than 1/10 of max deflection	At 40 kg load, door rests on the frame[a]	At 20 kg load, door rests on the frame[a]	At 10 kg load, door rests on the frame[a]
6	Impact indentation	No cracking, tearing or delamination. Depth of indentation not greater than 0.2 mm	No crack or deformation Max. Indentation = 0.14 mm	No crack or deformation Max. Indentation = 0.3 mm	No crack or deformation Max. Indentation = 0.1 mm
7	Edge loading test (deflection in mm) Initial Reading	Deflection at max. Load not greater than 5 mm. Residual deflection after removal of load not greater than 0.5 mm	10.6	12.6	12.7
	After 15 min of 100 kg loading	Not more than 2 mm during loading	4.8	5.1	4.9
	3 min after load removal	No residual buckling after load removal	No residual buckling	No residual buckling	No residual buckling
8	Shock resistance	No visible damage	No visible damage or delamination	No visible damage or delamination	Shock resistance
	Soft and light body impact				Soft and light body impact
	Soft and heavy body impact	No visible damage	No visible damage or delamination	No visible damage or delamination	Soft and heavy body impact
9	Buckling resistance test (deflection in mm)	No deterioration	No deterioration	No deterioration	No deterioration
	After 5 min of 40 kg loading	Initial deflection not more than 50 mm	104.3	155	156.3
	15 min after load removal	Residual deformation after 15 min of load removal not greater than 5 mm	16.8	23.4	27.4
10	Slamming test	No visible damage after 50 drops	No visible damage	No visible damage	No visible damage
11	Misuse	No permanent deformation of the fixing or any other part of the doorstep in hindering it's normal working after the test	No permanent deformation	No permanent deformation	No permanent deformation

[a] Maximum deflection limit of door testing equipment for Flexure test: 120 mm

Table 4 Results of 35 mm thick panel door shutters

S.No	Tests	Minimum value for conformity	C1	C2	C3
1	Dimensions (mm)				
	Length	Length ± 5 mm	2006	2003.5	2003.5
	Width	Width ± 5 mm	707.5	901.5	1104
	Thickness	Thickness ± 1 mm	35.13	35.5	34.59
2	Squareness (mm) Deviation per 500 mm length	Squareness not more than 0.5 mm per 500 mm length	2.92	2.21	0.825
3	General flatness (mm)				
	Twisting	Twist, cupping and warping not greater than 6 mm	0.175	2.05	0.05
	Cupping		0.42	0.35	0.575
	Warping		0.25	1.55	0.25
4	Local planeness (mm)	Depth of deviation not greater than 0.5 mm	0	0	0
5	Flexure mm 15 min after loading 50 kg 3 min after load removal	Deflection at maximum load not greater than 1/30 of length and 1/15 of width, whichever is less. Residual deflection not greater than 1/10 of max deflection	At 30 kg load, door rests on the frame[a]	At 20 kg load, door rests on the frame[a]	At 10 kg load, door rests on the frame[a]
6	Impact indentation	No cracking, tearing or delamination. Depth of indentation not greater than 0.2 mm	No crack or deformation Max. Indentation = 0.17 mm	No crack or deformation Max. Indentation = 0.23 mm	No crack or deformation Max. Indentation = 0.98 mm
7	Edge loading test (deflection in mm) Initial Reading	Deflection at max. Load not greater than 5 mm. Residual deflection after removal of load not greater than 0.5 mm	9.5	11.5	12.7
	After 15 min of 100 kg loading	Not more than 2 mm during loading	4.2	4.4	4.9
	3 min after load removal	No residual buckling after load removal	No residual buckling	No residual buckling	No residual buckling
8	Shock resistance soft and light body impact	No visible damage	No visible damage or delamination	No visible damage or delamination	Shock resistance Soft and light body impact
	soft and heavy body impact	No visible damage	No visible damage or delamination	No visible damage or delamination	Soft and Heavy body impact
9	Buckling resistance test (deflection in mm)	No deterioration	No deterioration	No deterioration	No deterioration
	After 5 min of 40 kg loading	Initial deflection not more than 50 mm	95.1	124.1	148
	15 min after load removal	Residual deformation after 15 min of load removal not greater than 5 mm	12.4	18	25.4
10	Slamming test	No visible damage after 50 drops	No visible damage	No visible damage	No visible damage
11	Misuse	No permanent deformation of the fixing or any other part of the doorstep in hindering it's normal working after the test	No permanent deformation	No permanent deformation	No permanent deformation

[a] Maximum deflection limit of door testing equipment for Flexure test: 120 mm

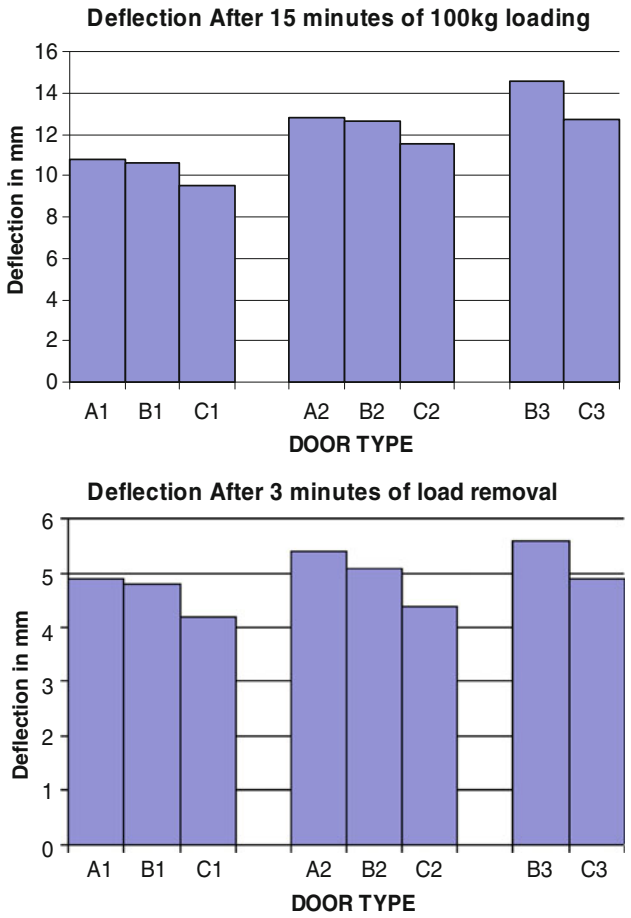

Fig. 2 Comparison of edge loading test results

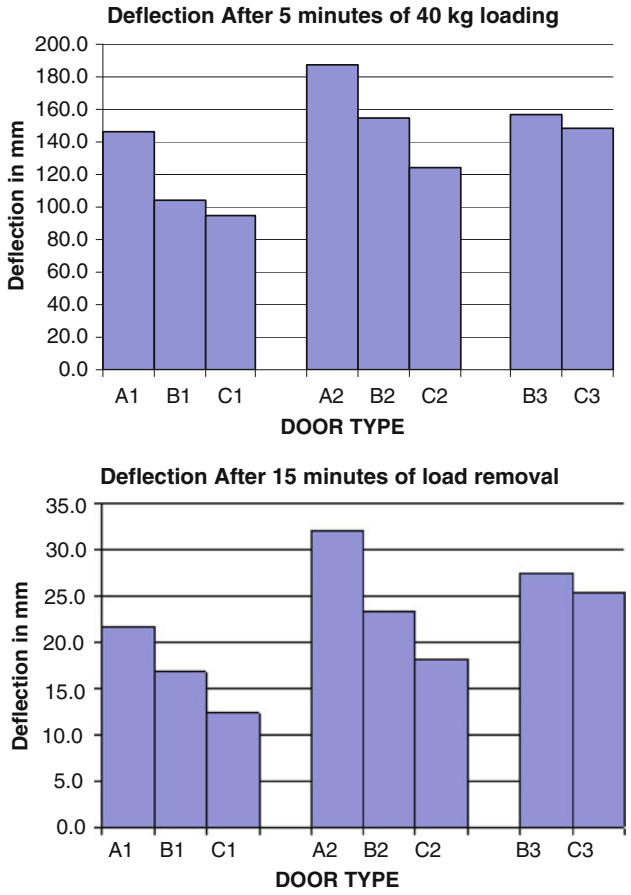

Fig. 3 Comparison of buckling resistance test results

door shutters are kept same as flush door shutters), where the stresses after loading are transferred to skin, which provides some resistance to deflection. In case of panel doors, in the absence of skins, it is less stiffer than the flush door shutter, which leads to more deflection when compared to Flush door, as shown in Fig. 4.

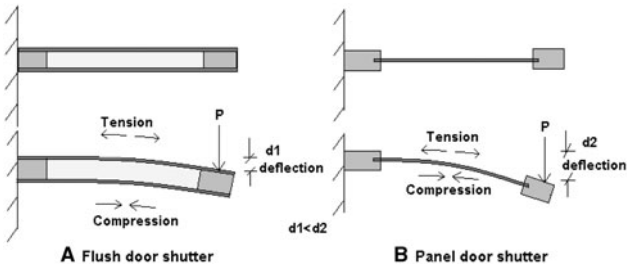

Fig. 4 Deflection of door shutters after loading

Conclusion

It is found that the performance of doors made of 30 mm thick rails and stiles are comparable with doors made out of 35 mm thick rails and stiles for all widths. Hence, 30 mm thickness can be recommended to Bureau of Indian Standards (BIS) for panel door manufacturing, which will save about 15% consumption of wood and thereby saving the natural resources. Wood conservation is highly desirable in the present context of wood raw material shortage.

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